1.0

4.5
5.0
5.6
6.3

2.8   2.5

3.2   2.2

3.6

4.0   2.0

1.1

1.8

1.25   1.4   1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
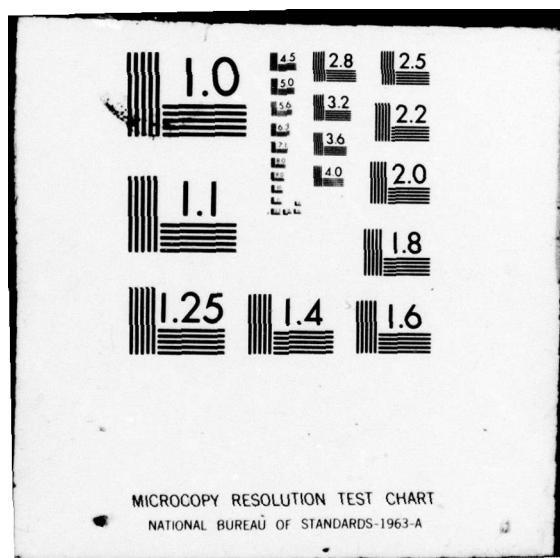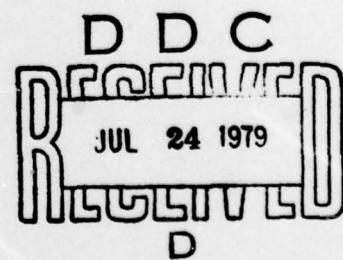
LEVEL II

(10)

AD A071597

HUMAN FACTORS IN COMPUTER SYSTEMS:
REVIEW OF THE LITERATURE AND
DEVELOPMENT OF DESIGN AIDS
(FINAL REPORT)

Technical Report SAI-79-113-DEN

Science Applications, Inc.
7935 E. Prentice Avenue
Englewood, CO 80111

31 July 1979

D D C
RECEIVED
JUL 24 1979
D

79 07 23 051

SAI

Science Applications, Inc.

40 Denver Technological Center West, 7935 East Prentice Avenue, Englewood, Colorado 80111, 303/773-6900

Other SAI Offices: Albuquerque, Ann Arbor, Arlington, Atlanta, Boston, Chicago, Huntsville, La Jolla, Los Angeles, McLean, Palo Alto, Santa Barbara, Sunnyvale, and Tucson.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Human Factors in Computer Systems: Review of the Literature and Development of Design Aids (Final Report)	Final Report. 1 June 1976 - 31 July 1979
	6. PERFORMING ORG. REPORT NUMBER SAI-79-113-DEN

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
H. Rudy Ramsey	N00014-76-C-0866

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Science Applications, Inc. 7935 E. Prentice Avenue Englewood, CO 80111	NR196-146

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Office of Naval Research 800 North Quincy Street Arlington, VA 22217	31 July 1979
	13. NUMBER OF PAGES 8 pages

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

human factors engineering, bibliographies, computers, man machine systems, interfaces, interactions, literature surveys

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the final report of Contract N00014-76-C-0866, covering a broad descriptive and critical survey of the literature on human factors in computer systems. The basic purpose of this effort was to assess the current state of the art in this area in order to evaluate the feasibility of developing a human factors guide to computer system design.

(see continuation next page)

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73

Two technical reports were issued under this contract. The first is a criti-
cally annotated and heavily indexed bibliography of 564 reports selected from
the surveyed literature. The second is a critical overview of the state of
the art, with recommendations for a design guide. The basic conclusion of
this study is that a human factors design guide for interactive systems --
which discusses issues, alternatives, and methods in the context of the
design process -- is both feasible and needed. The current state of the art
was not found adequate to support the development of a quantitative reference
handbook in this area.

Accession For

NTIS GRA&I	X
DDC TAB	
Unannounced	
Justification	

By

Distribution/

Availability Codes

Dist	Avail and/or special
A	

TO: Chief of Naval Research, Arlington, Virginia 22217
         Attention: Engineering Psychology Programs, Code 455,
         Dr. John J. O'Hare

FROM: H. Rudy Ramsey, Science Applications, Inc.
         Englewood, Colorado 80111

SUBJECT: Final report of work completed under the support of Contract
         N00014-76-C-0866, between Science Applications, Inc., and the
         Engineering Psychology Programs, Office of Naval Research.

This constitutes a final report of work completed under the support of
Contract N00014-76-C-0866, Work Unit Number NR196-146, between Science
Applications, Inc. and the Engineering Psychology Programs, Office of
Naval Research. The contract was initiated 1 June 1976, and was ter-
minated 31 July 1979.

The mission of this contract was to survey the literature in the area of
human factors in computer systems. Immediate goals were: (1) the
development of a bibliography describing and critically evaluating the
important individual papers in the field, and (2) the development of an
integrative and critical evaluation of the state of the art in the area.
This state-of-the-art survey was intended primarily to assess whether
our current knowledge in this area is adequate to develop a human factors
guide to computer system design.

The remainder of this report provides an overview of the research per-
formed under this contract, outlines our conclusions, and lists the
publications resulting from the study.

LITERATURE SURVEY

Human factors in computer systems is by nature a highly inter-
disciplinary field. As a result, the relevant literature is widely
scattered. Those who would perform effective application work in this
area must be aware of a broad range of literature, including: (a) the
general literature on human factors, as well as that concerned specifi-
cally with computer systems, displays, data entry, and specific appli-
cation areas; (b) a significant segment of the basic psychological
literature, including especially the areas of perception, information
processing, and cognitive psychology; and (c) a significant segment of
the computer science literature, including especially the areas of
batch and interactive languages, display and input devices and tech-
niques, and specific application areas.

Prior to this research project, this broad literature had not been
satisfactorily surveyed in recent times. With an increasing breadth
and volume of literature in the field, it has become increasingly diffi-
cult for researchers, new human factors personnel, and system designers
to acquire and maintain familiarity. There was a clear need for greater
synthesis of this information into a form useable by such personnel.
The form which has the greatest potential payoff in terms of research
utilization is a human factors guide to computer system design.

As a first step in integrating this information, a very broad
survey of the literature dealing with human factors in computer systems
was performed. Included in the survey were books, journal articles,
proceedings papers and institutional publications from the literatures
of psychology, human factors, and computer science. From the resulting
list, 564 references were selected for inclusion in a bibliography.

The references selected deal primarily with the human factors
aspects of interactive computer systems, including hardware, software
and procedures. The selection of references emphasizes experimental
studies, but the bibliography also includes relevant descriptions of

2

dialogue techniques, user requirements analysis methods, guidelines, and a variety of other relevant topics.

For each reference, the bibliography presents a citation with sufficient information to allow the reader to obtain a copy. For each reference, both a descriptive abstract and a critical annotation are presented. An extensive subject index, as well as an author index and browsing aids, allow the location of documents of interest to a particular user.

The bibliography is reference 1 in the list of technical reports at the back of this final report.

STATE-OF-THE-ART REVIEW

Although the bibliography was intended to be useful in itself, its more important function in this project was as the initial step toward a critical, integrative review of the state of the art in the area. Such a review report was prepared. This proved to be a difficult task, primarily because it attempted to integrate information at a fairly detailed level across a very broad field.

The review report attempts to describe the current state of the art in human factors research and in actual practice in the design of interactive systems. The report covers such topics as:

> User and Task Properties
> Requirements Analysis Techniques
> Problem-solving Aids
> Interactive Dialogue
> Output Devices and Techniques
> Input Devices and Techniques

Wherever possible, the report presents this descriptive information in the form of tables, with critical comments and references to the most relevant source documents.

The main emphasis throughout this report was on the information needs of the system designer and on the feasibility and nature of human factors guidelines which might satisfy those needs. The principal conclusion was that insufficient data exist for the development of a "quantitative reference handbook" in this area, but that a "human factors design guide" -- which discusses issues, alternatives, and methods in the context of the design process -- is both feasible and needed.

This conclusion results from two principal factors. First, the research literature, while quite large, is fragmented and inadequate to support anything approaching a quantitative reference handbook of

the type produced in classical human engineering areas. Second, and perhaps even more important, it is not clear that the problem-solving behavior of the interactive system designer is consistent with such a reference work.

The design decisions for which a reference handbook is used must be explicitly identified by the designer. In "classical" system design situations, this may be a reasonable expectation. When a design engineer encounters issues such as level of illumination, size of control knobs, or type and position of a numerical display, the design decision involved tends to be: (1) quantitative, (2) explicit, and (3) clearly associated with the "operator interface", and therefore closely identifiable with human factors. Even here, there is evidence which suggests that designers may proceed without consulting readily available human factors handbooks.

In the design of interactive computer systems, virtually every decision which affects the functional behavior of the system has direct human factors overtones. This claim can be made in the cases of automobiles, aircraft, and radios, too, but only in a much weaker sense. In a system whose basic function is communication with a user, and whose basic purpose often is to assist the user with tasks which are cognitive or informational in nature, human factors issues pervade the entire design process.

Furthermore, the important design decisions may not be explicitly recognized. It appears that the primary problem-solving method employed in design tasks is an "analytic/synthetic" approach. This approach involves an analysis of the design problem, in which the components of the problem are identified, followed by the synthesis of a solution. It does not involve an explicit search for alternative solutions; instead, a solution is "synthesized" based on pattern recognition and the use of components from past solutions to other problems.

If, in interactive systems, the design decisions which involve human factors issues are pervasive, implicit, and often qualitative, a

reference handbook is unlikely to be effective. However, there is
another mechanism for providing human factors guidance to the system
designer, which appears to be more compatible with the design process
and the designer's information needs. It also appears to be more
compatible with the current state of our knowledge. This approach
is the design guide.

As the term is used here, a "design guide" is a document whose
structure parallels the major steps of the design process itself.
Although such a guide should be indexed sufficiently that it can be
consulted with a specific question after that question has been identi-
fied, that is not the design guide's primary mode of use. It is intended
to be consulted during the analytic process, before design decisions are
made. Such a guide must identify issues, suggest alternatives, and present
(where they exist) hard human-factors data at the point in the design pro-
cess at which this information is most relevant.

Clearly, this is more of a "how-to-do-it" document than has typi-
cally been undertaken by human factors personnel. Sucn an approach
appears justified, however, by several factors: (1) the pervasiveness
of human factors issues throughout the interactive system design process;
(2) the likelihood that a reference handbook would not be consulted and
used effectively; (3) greater compatibility with the problem-solving
behavior and information needs of the system designer; (4) inadequacy
of the existing human factors data base to support development of a
quantitative reference handbook; (5) comprehensiveness, in the sense that
this format allows discussion and some guidance even in areas in which
specific experimental data are lacking; and (6) the fact that this general
format is capable of encompassing not only human factors data, but also
applied human factors methods.

The review report attempts to indicate for each topic covered, the
availability and quality of existing guidelines which could be inte-
grated into such a document, and/or the nature and difficulty of the
effort required to formulate such guidelines in areas in which existing

6

guidelines are inadequate. The review report is reference 2 in the
list of Technical Reports, which follows.

TECHNICAL REPORTS

1. Ramsey, H. R., Atwood, M. E., & Kirshbaum, P. J. A critically
   annotated bibliography of the literature on human factors in
   computer systems (Technical Report SAI-78-070-DEN). Englewood,
   Colorado: Science Applications, Inc., May 1978. (NTIS No.
   AD A058081; JSAS No. MS-1822)

2. Ramsey, H. R., & Atwood, M. E. Human factors in computer systems:
   A review of the literature (Technical Report SAI-79-111-DEN).
   Englewood, Colorado: Science Applications, Inc., July 1979.

DISTRIBUTION LIST

Director,   (5 copies)
Engineering Psychology Programs
Code 455
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Commanding Officer
ONR Branch Officer
Attn: Dr. C. Davis
536 S. Clark Street
Chicago, IL 60605

Defense Documentation Center   (12 copies)
Cameron Station, Building 5
Alexandria, VA 22314

Director,   (6 copies)
Naval Research Laboratory
Attn: Code 2627
Washington, D.C. 20375

Office of Naval Research   (6 copies)
Attn: Code 102IP
Department of the Navy
Arlington, VA 22217

Defense Contract Administration
    Services Management Area - San Diego
Building 4, AF Plant 19
4297 Pacific Highway
San Diego, CA 92110